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Method and apparatus to measure a borehole

The invention concerns a method and apparatus to measure a borehole in a ground, whereby by means of an inclinometer the angle of inclination of the borehole relative to the vertical is measured over its depth. The invention further concerns an apparatus to measure a borehole.

In the case of known methods of the above described kind first a borehole is sunk in the ground by means of a boring bar. After withdrawing the boring bar from the borehole a measuring bar is lowered into the hole. The inclinometer is arranged within a guide block that rests again the wall of the borehole. The guide block is lowered step-by-step, so that the angle of inclination is measured step-by-step. Such a method is described in the VDI Lexicon, Bauingenieurwesen, Düsseldorf, VDI Verlag 1991. [VDI=Association of German Engineers, Bauingenieurwesen=civil engineering, Verlag=publisher]. This method, however, requires the use of a measuring bar, that is lowered into the borehole after its completion. Thus the measuring of boreholes is time consuming and uneconomical.

The object of the invention is to provide a method and an apparatus to measure a borehole whereby the measurings carried out are less time consuming and the apparatus produced can be less expensive.

According to the invention this objective is achieved by a method, whereby an inclinometer, fastened at the bottom end of a boring bar, is introduced into the borehole by the boring bar, particularly a rotatably driven one, during its sinking, during sinking the orientation of a horizontal reference axis of the inclinometer is transmitted to the top end of the boring bar, after reaching the final depth the

boring bar is stopped and is rotated to a reference direction and during the withdrawal of the boring bar from the borehole the angle of inclination and the direction of inclination of the inclinometer is measured by the inclinometer over the depth of the borehole. The angle of inclination represents the deviation from the vertical, while the direction of inclination indicates the direction of the inclination relative to the horizontal reference axis.

When preparing foundations for building sites by using the injection method, injection agent is injected under pressure into the ground to reinforce it, commencing from the boreholes. The boreholes are so arranged, that they overlap the areas of the reinforced ground and consequently form an enclosed foundation. In this case the boreholes can deviate from the vertical when, for example, layers of rocks or solid layers have to be passed through. Thus the base of the borehole may considerably vary from the planned position. However, to ensure an overlap of the reinforced areas of the ground without gaps occurring in the foundation, in the case of the method according to the invention the boreholes can be measured during the withdrawal of the boring bar. Thus in the case of great deviations correcting steps can be carried out prior to the commencement of the next boring operation.

To ensure a spatial measuring of the angle of inclination, one component of the angle of inclination can be measured in each of two vertical planes which are perpendicular relative each other.

Various methods may be used to determine the course of the angle of inclination. The boring bar may be withdrawn, commencing from the final depth, step-by-step, while the angle of inclination of the inclinometer is measured after each step along the depth of the borehole. The boring bar may also be continuously withdrawn from the borehole, while the angle of inclination of the inclinometer is continuously recorded along the depth of the borehole or the angle of inclination is measured at certain time or depth intervals along the depth.

To enable to form an opinion regarding the deviation of the position of the base of the borehole the spatial course of the borehole is determined from the course of the angle of inclination of the inclinometer along the depth of the borehole.

Because in the case of a boring bar that rotates while being introduced into a borehole no cable can be run from the inclinometer to the surface, the angle of inclination can be measured by means of the inclinometer at time intervals and stored, as well as the depth position of the boring bar can be measured at time intervals and stored in a separate measuring equipment, situated outside of the borehole.

The spatial progress of the borehole can then be determined by correlating the angle of inclination of the inclinometer and the depth position of the boring bar at time intervals.

When in the following the angle of inclination is addressed, it always includes the angle relative the vertical and the angular orientation relative the reference direction.

The objective is further achieved by an apparatus to measure a borehole, that comprises a boring bar, in particular one that can be rotatably driven about a longitudinal axis and has a tubular construction, an inclinometer fastened at the bottom end in the boring bar to measure the angle of inclination, and means with which the orientation of a horizontal reference axis of the inclinometer can be transmitted to the top end of the boring bar.

Since in the case of rotatably driven boring bars no cables can be run from the inclinometer to the surface and slip-ring contacts are difficult to execute as well as in most cases a radio transmission of the measured values is not possible, the inclinometer comprises an independent current supply, a timer and a data storage to store the angles of inclination and times measured.

The inclinometer preferably comprises means which keep the inclinometer in an approximately vertical position and switched on in the non-rotating state and

switched off in positions deviating from those and/or in the rotating state. By virtue of this measurements during the sinking of a borehole or when the boring bar is in the horizontal position, will be avoided.

A preferred embodiment provides that at the bottom end of the boring bar a boring head is provided with at least one flow-through channel that enables the passing through of the boring head by a flushing fluid, as well as with means that accommodate the inclinometer while protecting it against the flushing fluid and fasten it in the boring head.

Preferred embodiments are described based on the drawings.

They show in:

Fig.1 - the view of a boring equipment comprising a crawler-type vehicle and a boring bar, with which a borehole is produced in the ground,

Fig.2 - a tubular section of the boring bar with a device to accommodate an inclinometer, longitudinally sectioned.

Fig.1 shows a boring equipment 1, a vertically positioned leader 2 and a boring bar 3. At its top end the boring bar 3 is joined with the leader by a mounting 4 and its swivel 5. The mounting 4 and the swivel 5 can move vertically on the leader 2. The swivel 5 serves the purpose of connecting leads to introduce, for example, suspension, water or air, while the leads are not illustrated. Below the mounting 4 a rotary head 6, that can be vertically moved on the leader 2, is provided to drive the boring bar 3. The boring bar 3 passes through the rotary head 6. To sink a borehole 7 into a foundation 8 the mounting 4 and the rotary head 6 and thus the boring bar 3 is lowered.

The boring bar 3 comprises a plurality of tubular sections 9, 9', 9", a boring head 10 as well as a cutter 11 at the bottom portion of the boring bar 3. The tubular sections 9, 9', 9" and the boring head 10 are screwed together. At the top end of the boring bar 3 it is rotatably driven by the boring head 6. At the bottom end of

the leader 3 *[should read 2]* a supporting device 12 is provided, by means of which the boring bar 3 is axially guided. In the boring head 10 an inclinometer 13 is provided that measures the incline of the boring head 10 and consequently that of the borehole 7.

Prior to sinking the borehole 7 the orientation of a horizontal reference axis of the inclinometer 13 is transmitted to the top end of the boring bar 3.

If, as illustrated, the boring bar 3 comprises several tubular sections 9, 9', 9" screwed together, this procedure has to be carried out after each attachment of a new tubular section 9, 9', 9". In this connection first the boring head 10 with the inclinometer 13 is rotated to a reference direction. At the top end of the leader 2 the rotated position of the boring bar 3 relative to the leader 2 is marked at the top end of the boring bar 3. After sinking a section of the borehole 7, therefore after introducing the tubular section, the boring bar 3 is rotated again to the marked rotated position relative the leader 2. After attaching the next tubular section the rotated position of the boring bar 3 relative to the leader 2 is marked at the top end of the new tubular section. This procedure is repeated every time prior to attaching a new tubular section.

After reaching the final depth the boring bar 3 is stopped, so that it will no longer rotate. Afterward the boring bar 3 is rotated to a reference direction. By virtue of this the inclinometer 13 is unambiguously fixed relative to a stationary reference system, for example in the North-South direction or an axis of the construction. The boring bar 3 is withdrawn in the non-rotating state from the borehole 7, while the angle of inclination is measured. The boring bar 3 can be withdrawn from the borehole 7 step-by-step. By doing so the angle of inclination of the inclinometer 13 is measured after each step over the depth of the borehole 7. It is also feasible to continuously withdraw the boring bar 3 from the borehole 7. In this connection the angle of inclination can be continuously recorded over the depth or measured at certain time or depth intervals.

Fig.2 shows the longitudinally sectioned boring head 10 according to Fig.1. At its ends the boring head 10 has tapered internal threads 14, 15. A further tubular

section can be screwed into the top internal thread 14 via a joining piece. Into the bottom internal thread 15 a joining piece 16 is screwed in, that has a tubular construction and at each of its end has a tapered external thread 17, 18. Onto the bottom tapered external thread 17 a cutter can be screwed. An inner tube 19 is provided coaxially with the boring head 10. At the top end of the inner tube 19 a bottom 20 is provided. At the bottom end of the inner tube 19 a cover 21 is screwed into the internal thread 22 of the inner tube 19. In this manner a hollow space 23 is formed, in which the inclinometer can be accommodated. The inner tube 19 is kept at a radial distance from the internal surface 25 of the boring head 10 by means of pins 24. At its ends the inner tube 19 has metal plates 28, 29, the purpose of which is to ensure a radial distance of the inner tube 19 from the internal surface 25 of the boring head 10 on the one hand and the axial position of the inner tube 19 on the other.

The joining piece 16 axially rests against the metal plate 28 at the bottom end of the inner tube 19 and presses the inner tube 19 with the metal plate 29 at the top end of the inner tube 19 against an annular shoulder 30 in the boring head 10. Between an external surface 26 of the inner tube 19 and the internal surface 25 of the boring head 10 an annular flow-through channel 27 is formed. Thus flushing fluid can be introduced into the boring head 10 that can flow through the flow-through channel 27 and flow into the cutter screwed into the bottom end of the boring head 10.

Patent claims

1. A method to measure a borehole (7) in a ground (8), whereby an inclinometer (13), that is fastened in the bottom end of a boring bar (3), is introduced into a borehole (7) by means of the particularly rotatably driven boring bar (3) while it is sunk into the borehole, during sinking the orientation of a horizontal reference axis of the inclinometer (13) is transmitted to the top end of the boring bar (3), after reaching the final depth the boring bar (3) is stopped and is rotated to a reference direction and during the withdrawal of the boring bar (3) from the borehole (7) the angle of inclination and the direction of inclination of the inclinometer (13) is measured by the inclinometer (13) along the depth of the borehole (7).

2. A method according to claim 1, characterised in that with the inclinometer (13) one component of the angle of inclination is measured in each of two vertical planes which are perpendicular relative each other.

3. A method according to any one of claims 1 or 2, characterised in that commencing from the final depth the boring bar (3) is withdrawn from the borehole (7) step-by-step and that the angle of inclination of the inclinometer (13) is measured after each step along the depth of the borehole (7).

4. A method according to any one of claims 1 or 2, characterised in that commencing from the final depth the boring bar (3) is continuously withdrawn from the borehole (7) and that the angle of inclination of the inclinometer (13) is continuously recorded along the depth of the borehole (7).

5. A method according to any one of claims 1 or 2, characterised in that commencing from the final depth the boring bar (3) is continuously withdrawn from the borehole (7) and that the angle of inclination of the inclinometer (13) is continuously measured at certain time or depth intervals along the depth.

6. A method according to any one of claims 1 to 5, characterised in that the spatial progress of the borehole (7) is determined from the course of the angle of inclination of the inclinometer (13) along the depth of the borehole (7).

7. A method according to any one of claims 1 to 6, characterised in that the angle of inclination is measured at time intervals by means of the inclinometer (13) and it is stored and that in a separate measuring equipment, situated outside of the borehole (7), the depth position of the boring bar (3) is measured at time intervals and is stored.

8. A method according to claim 7, characterised in that the spatial progress of the borehole (7) is determined at time intervals by correlating the angle of inclination of the inclinometer (13) and the depth position of the boring bar (3).

9. An apparatus to measure a borehole (7), comprising a boring bar (3), in particular one that can be rotatably driven about a longitudinal axis and has a tubular construction, an inclinometer (13) to measure the angle of inclination that is fastened at the bottom end in the boring bar (3), and means with which the orientation of a horizontal reference direction of the inclinometer (13) can be transmitted to the top end of the boring bar.

10. An apparatus according to claim 9, characterised in that the inclinometer (13) comprises an independent current supply, a timer and a data storage to store the angles of inclination and times measured.

11. An apparatus according to any one of claims 9 or 10, characterised in that the inclinometer (13) comprises means that keep the inclinometer (13) in an approximately vertical position and switched on in the non-rotating state and switched off in positions deviating from those and/or in the rotating state.

12. An apparatus according to any one of claims 9 to 11, characterised in that at the bottom end of the boring bar (3) a boring head (10) is provided with at least one flow-through channel (27) that enables the passing through of the boring head (10) by a flushing fluid, as well as with means (19, 21) that accommodate the inclinometer (13) in a sealing manner against the flushing fluid and fasten it in the boring head (10).

13. An apparatus according to any one of claims 9 to 12, characterised in that the boring bar (3) comprises a plurality of tubular sections (9, 9', 9") that are screwed together.